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TESTING OF USAID-TYPE HANDPUMP (HONDURAS)

WASH FIELD REPORT NO. 130

SEPTEMBER 1984

Prepared for:
Office of Health
Bureau for Science and Technology
U.S. Agency for International Development
Under Order of Technical Direction No. 72

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Compiled by

David Donaldson

From a Report By Consumer's Association of England
And Comments By Georgia Institute of Technology

September 1984

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Table of Contents

Page

Appendices

Tables

Figures

EXECUTIVE SUMMARY

In 1981, WASH obtained from a Hondurian* manufacturer two locally manufactured USAID-type handpumps and shipped them to the Consumer's Association (CA) Harpenden Rise Testing Laboratory in Harpenden, England. The two pumps were bench tested and reported on following the protocols and reporting procedures developed for the World Bank's Handpump Testing Program.

During the course of the test USAID/WASH was informed that there were notable differences between the CA procedures and those used by the Georgia Institute of Technology (GIT) at the USAID handpump testing facility in Atlanta, Georgia.

These differences were as follows:

ITEM	CA	GIT
Lubrication	Initial lubrication only	Initial lubrication plus re-lubrication during regular checkups
Setting of head valves	Shallow well-7 meters Deep well-25/45 meters	-100 feet -Raised to 300 ft

The stroke speed (40 cycles per minute) and handle movement (within the stops) were the same for the CA and GIT tests.

The purpose of the test was to have data on the locally-made Hondurian USAID-type handpump be compatible with the data being reported by CA on 30 different types of handpumps. This testing was to be complemented by the GIT testing at Atlanta. A major difference between those two tests was that the Atlanta test was to compare locally manufactured USAID-type pumps; whereas, the CA test compared different kinds of internationally available pumps.

The CA test results showed that the two Hondurian pumps did not have interchangeable parts and that no installation or operating data were provided with the pump. CA also concluded that the design required a substantial complement of tools and equipment and a good deal of skill and experience to install.

During testing of the Hondurian pumps, the leather foot valve broke and became loose in the cylinder causing the pump rod to bend. The tests also showed that after 89,000 cycles the top of the pump stand had worked loose from the threaded connection with the column and caused a leak.

*accepted adjective according to sources at PAHO.

From its testing the CA concluded that:

- The Hondurian AID-type handpump is robust enough to be suitable for use in a developing country community water supply program if the local manufacturer has well established iron foundry skills and effective quality control procedures.
- There are a number of design changes that should be considered to improve the assembly and/or use of the pump.
- The flap-type foot valve is worse than redundant because it can break away and damage the plunger. The design and material for this valve should be greatly improved or it should be eliminated in favor of a brass foot valve.
- The misfit of the parts highlighted the need for using jigs and fixtures so that all similar parts would be interchangeable.

WASH reviewed the report and GIT's comments and made the following recommendations:

Recommendation #1: While on the whole the design of the USAID-type handpump was satisfactory, there are several desirable design changes: a more resilient handle, enlarged flanges, a scalloped spout, and simpler handle, fulcrum, and crosshead mechanisms.

Recommendation #2: The leather flap-type foot valve should be modified or eliminated.

Recommendation #3: The use of jigs and fixtures should be made a part of any future manufacturing effort to ensure the interchangeability of parts.

Chapter 1

BACKGROUND

1.1 Consumer's Association Test

In 1981 WASH obtained two locally manufactured USAID-type handpumps from Honduras and had them shipped to the Consumers' Association (CA) Harpenden Rise Laboratory in Harpenden, England. There the pumps were tested according to the protocols developed for the World Bank Handpump Testing Program. Table 1.1 summarizes these procedures (see Appendix A for the detailed procedures).

At the end of the 1,000 and 4,000 hours of testing, CA provided interim reports on the results obtained (see Appendix B). In addition, CA issued a pump failure alert sheet covering the failure of the flap-type foot valve (see Appendix C). These materials were shared with the WASH handpump sub-contractor, Georgia Institute of Technology (GIT), for use as references in designing the AID handpump facility at Atlanta, Georgia.

Once CA completed its testing of the Hondurian handpump (manufactured by FUNYMAQ) it provided its conclusions to WASH in a report that followed the World Bank format (see Appendix D). Using this format allowed the data to be compared with the results of the other pumps being tested by CA for the World Bank. WASH provided a copy of the CA report to GIT for its review and comments. GIT's comments and CA's clarification are presented in Appendix E.

1.2 Points To Be Noted in the CA Test Procedure

In reviewing the CA test data one needs to be aware of the following differences between the GIT and World Bank testing procedures.

1.2.1 Lubrication

CA reported: "When the pumps were installed all moving parts were correctly lubricated. During the course of the endurance test no further lubrication was provided since it cannot be assumed that regular lubrication will occur in the field. If any components failed in the endurance test requiring the pumps to be dismantled, then correct lubrication was given on re-assembly." In the GIT test the pumps were disassembled at regular intervals and were relubricated prior to continuing the testing.

1.2.2 Setting of Head Simulation Valves

CA reported: "This valve was set either to operate at 7 meters for a shallow well or 25 meters and 45 meters (or greatest depth recommended by the manufacturer) for the operation of the deep well pump, whichever was the lower figure." In the GIT test the head simulation valves were set for 100 feet. Later in the test this was raised to 300 feet.

1.2.3 Performance Stroke Speeds

CA reported: "For force pumps the endurance stroke speed was selected at 40 per minute, as being the highest rate sustainable by a person to fill a 20 liter container. In the performance test the pump rates included 50 strokes per minute since this is humanly possible for a short duration.... For suction pumps a maximum speed of 30 strokes per minute was selected for the endurance test, as operating above this speed produced cavitation under the plunger. Accepting cavitation, the suction pumps functioned at 40 strokes per minute, and this speed was therefore included in the performance test." In the GIT test a constant test speed of 40 cycles per minute was used.

1.2.4 Handle Movement

CA reported: "In all cases the arc of handle movement was selected to be just within the limit of the stops to avoid the risk of uncontrolled banging of the handle, which was the subject of a separate abuse test." A similar procedure was used by GIT in its test.

1.3 Purpose of Testing

The purpose of this task (OTD-72) was to conduct a test on the locally manufactured Honduran handpump following the World Bank protocols. The result of this comparative test will be made a part of the World Bank's report on handpump testing which is to have a wide circulation. It is planned that on completion of its current test program, CA will have tested and reported on 30 different types of handpumps currently available on the world market.

This test will be complemented by the testing to be done at the USAID handpump facility at Atlanta, Georgia. The main difference between the CA and GIT tests is that at Atlanta the emphasis is on conducting comparative tests of locally manufactured USAID-type pumps whereas at CA the emphasis is on comparative testing of internationally available pumps.

Chapter 2

TEST RESULTS

2.1 General

In its report CA presented test results for the following areas:

- Results of shipping inspection
- Installation data
- Weights and measures
- Engineering assessment
- Pump performance
- User trial
- Endurance
- Abuse tests
- Verdict

Appendix D contains the full report. The following sections summarize the data presented in the CA report.

2.2 Results of Shipping Inspection

CA found that the open-slatted wooden case in which the pumps were packed did not provide enough protection during shipment. For example, the crate bases were weak enough for the connecting rods to push through and be bent.

When the pumps were assembled, CA found that the pump caps could not be placed on the bodies because the holes in the pump caps were drilled in the wrong position. It was also found that the cast iron parts had not been flushed of casting sand and there was some evidence of porosity.

While GIT commented on these problems, it did not offer any reasons for and/or explanation of what happened (see Appendix E).

2.3 Installation Data

CA indicated that no installation or operating data were provided by the manufacturer. WASH was able to verify this. In addition, CA concluded that the design requires a substantial complement of tools and equipment and "a good deal of skill and experience to install..." (see Figure 2). GIT made no comment on this subject.

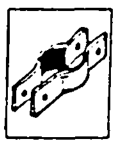
2.4 Weights and Measures

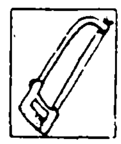
CA noted that there were "significant differences" between the Hondurian pump and a USAID-type pump that had been made in Indonesia. The Hondurian pump was much heavier (see Table 2 for weights and dimensions of the Hondurian pump).

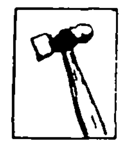
Figure 1

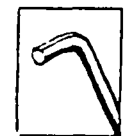
Requirements for Installation, Maintenance, and Repair

The equipment, level of skill and personnel required for installation, maintenance and repair are illustrated by the following symbols:

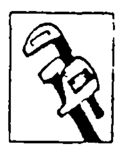

Clamp


Hacksaw

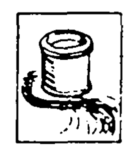

Hand Tools


Hexagon Key(s)


Lifting tackle


Pipe Wrench(es)


Flat Spanners


Jointing Materials


Lubricant (oil and/or grease)


Threading Die(s) and Die Stock


Skilled Person

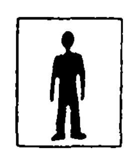

Labourer

Table 1

Summary of Terms of Reference for Handpump Testing at CA Harpenden Rise Laboratory

1. Obtaining Pumps	1.1 Manufacturer or agency 1.2 Pump model and type 1.3 Cost 1.4 Delivery time
2. Inspection	2.1 Packaging 2.2 Condition of pumps 2.3 Literature
3. Weights and Measures	3.1 Weights of principal components 3.2 Principal dimensions 3.3 Cylinder bores 3.4 Ergonomic measurements
4. Engineering Assessment	4.1 Materials, manufacturing methods, fitness for purpose 4.2 Suitability for manufacture in developing countries 4.3 Ease of installation, maintenance and repair 4.4 Resistance to contamination and abuse 4.5 Potential safety hazards 4.6 Suggested design improvements
5. Pump Performance	5.1 Volume flow, work input, and efficiency 5.2 Leakage
6. User Trial	6.1 User responses 6.2 Observation of users
7. Endurance Test	Four stages of 1,000 hours each, using four different and increasingly severe qualities of water: 7.1 Stage 1 - clean, hard water, approx. 7.2 pH 7.2 Stage 2 - clean, soft water, maintained at approx. 5.5 pH by adding hydrochloric acid, subject to a maximum chloride concentration of 1 g/litre 7.3 Stage 3 - hard water to which Keiselguhr, with a particle size of 7.5 um, was added in the concentration 1 g/litre of water 7.4 Stage 4 - hard water to which sharp quartz sand with a particle size between 75 and 500 um was added in the concentration 1g/litre of water For stages 3 and 4, the water to be agitated. At each 1,000 hour stage, the volume flow and leakage to be checked, and the pumps to be dismantled for inspection, and a full performance test carried out after 4,000 hours.
8. Abuse Tests	8.1 Side impacts on pump stand, up to 500 Joules and side impacts on handles up to 200 Joules 8.2 Handle shock load test at the endurance test stroke rate, where applicable: 96,000 impacts for force pumps 72,000 impacts for suction pumps
9. Review	9.1 Ease of pump installation 9.2 Ease of maintenance and repair 9.3 Verdict

Table 2

Hondurian Handpump
Weights and Measures

WEIGHTS & MEASURES

1.	Weights	Pump stand:	51.0 kg (including handle)
		Cylinder:	8.0 kg (including Simmons foot valve)
2.	Dimensions	Nominal cylinder bore:	70 mm
		Actual pump stroke:	190 mm
		Nominal volume per stroke:	731.ml
		Drop pipe size:	1.25 inch *
		Pump rod diameter:	7/16 inch *
		Outside diameter of below-ground assembly	105 mm
		Maximum usable cylinder length:	320 mm

* Not supplied but designed for these sizes.

3. Cylinder Bore — No significant taper or ovality was found in either of the two samples.

The surface roughness average (Ra) was measured in three places in a direction parallel to the cylinder axis.

SAMPLE	CYLINDER BORE	ROUGHNESS AVERAGE (ym)			
		TEST 1	TEST 2	TEST 3	MEAN
1	Extruded uPVC	1.5	1.7	1.4	1.5
2	Extruded uPVC	1.5	1.5	2.0	1.7

Measured at 2.5 mm cut-off

4. Ergonomic Measurements

HANDLE HEIGHT		PLATFORM HEIGHT (mm)	ANGULAR MOVEMENT OF HANDLE (degrees)	HANDLE LENGTH (mm)	VELOCITY RATIO OF HANDLE	HEIGHT OF SPOUT (mm)
MAX(1)	MIN(1)					
1310	280	0	90	730	5.8	470

(1) Measured without compressing any bump stops

2.5 Engineering Assessment

After examining the types of metal in the various parts (see Table 3), CA examined the feasibility of local manufacture of this type of pump and they concluded that such a pump could be successfully made in a developing country if the "necessary quality control could be assured."

After examining the design resistance to contamination, abuse, and potential safety hazards, CA went on to point out a series of suggested design improvements:

- Providing a handle of more resilient material (i.e., steel or wood) for ease of repair
- Enlarging the flanges on the pump stand body and cap to allow more clearance for bolts
- Improving or eliminating the flap-type check valve
- Venting or scalloping the spout to prevent fecal contamination
- Simplifying the handle fulcrum and eliminating the crosshead mechanism

GIT had no comment on these suggested design improvements.

Table 3

Construction Materials

Pump stand top	Cast iron	
Pump stand column and spout	Two iron castings, 1 steel pipe	
Handle	Cast iron	
Fulcrum link	Cast iron	
Handle fulcrum bushes	Hardened steel	Approximately 50 Rockwell C
Handle fulcrum pins	Hardened steel	
Connecting rod	Steel	
Eye	Cast iron	
Cylinder	PVC body with cast iron end caps	
Plunger assembly	Cast gunmetal	
Cup seal	Leather	
Foot valve in cylinder	Cast iron with leather flap	
Simmons foot valve	Cast gunmetal with rubber seal	

2.6 Pump Performance

Flow, work input, and efficiency are shown in Table 4 for different pumping rates and heads.

Table 4

Examples of Volume, Work Input, and Efficiency for Honduran Handpump

HEAD	7 m			25 m			45 m		
Pumping Rate (strokes/min)	29	38	51	20	29	37	21	30	37
Vol/stroke (litres)	0.69	0.70	0.70	0.69	0.69	0.69	0.68	0.69	0.68
Work input/stroke (J)	125	134	134		277	304	404	459	468
Efficiency (%)	37	35	35	64	61	55	74	66	64

Note: 1. The description of the methods used can be found in the test procedure.
2. Leakage from the foot valves was not significant (less than 0.1 ml/min) at the head tested.

2.7 User Trial

CA found that most users could operate the pump without difficulty. It noted that many muscle groups could be called into play without exaggerated body movements.

2.8 Endurance

The pump was tested at 40 strokes per minute at a simulated depth of 30 meters.

The Honduran pump proved to be much more durable than the Indonesian pump tested in 1981/82, although both pumps were derived from the same design. In particular the handle pivots, which had caused so much trouble in the latter, endured throughout the test. However, the flap-type leather foot valve broke away after 3,127 hours. The pump continued to work because the Simmons foot valve supported the column of water, but the broken parts of the foot valve became entangled in the plunger, bent the pump rod, and caused severe damage to the cylinder bore. In view of this failure, CA strongly recommended that the flap-type valve in the base of the cylinder should be omitted, or its quality should be much improved and the proprietary foot valve omitted.

In its comments, GIT expressed its agreement with the CA recommendation that the flap-type valve be improved or eliminated.

To show the durability of the pump the CA developed the breakdown data presented in Table 5 and the endurance test details shown in Table 6.

Table 5

Breakdown Incidence

Breakdowns are shown in bold type.

Hours:	1,062	2,112	3,127	4,169
0	1	1	1	1
1	1	1	1	1
1				
1	1	1	1	1
1	1	1	1	1
1	1	1	1	1
Inspection and full performance test	Inspection and volume flow	Inspection and volume flow	Inspection and volume flow	Inspection and full performance test
			1	
			1	
			Foot valve flap broken away, pump rod bent, severe damage to cylinder bore	

2.9 Abuse Tests

In the side impact tests CA found that the pump body tended to turn on the thread at the joint with the pump stand column in the handle test.

It also found that after 89,000 cycles, the top of the pump stand had worked loose on its thread at the connection with the column and caused a leak. The thread could be easily tightened and the pump maintained in working order.

Table 6

Details of the Endurance Test

Breakdowns are shown in **bold type.**

HOURS

1,062 Inspection after first 1,000 hours:

a. Slight wear in handle bearings and guide blocks
b. Spots of rust on cylinder end caps and plunger rod
c. The upper leather foot valve appeared to be no longer functional and had been deformed into a constant, open position

2,122 Inspection after second 1,000 hours:

a. Slight increase in wear in handle bearings and guide blocks
b. Larger spots of rust on cylinder end caps and considerable corrosion on plunger rod
c. Upper leather foot valve redundant

3,127 Inspection after third 1,000 hours:

a. **Severe damage to cylinder bore caused by parts of leather foot valve which had broken away and become entangled in the plunger. The plunger road had bent and the cylinder bore was deeply scored as a result. The cylinder assembly was replaced by the second sample**
b. Slight increase in wear in handle bearings and guide blocks
c. Further corrosion of cylinder end caps and plunger rod

Estimated Amount of Water Pumped to Breakdown........4.4 million litres

4,169 Final inspection

1	Cylinder	Replacement cylinder in good condition
2	Bearings	Considerable wear in handle bearings and guide blocks but all still serviceable
3	Pump stand	Hole in pump stand top enlarged by connecting rod
4	Corrosion	Considerable corrosion of cylinder end caps and plunger rod, the latter particularly around joint with plunger body

Estimated Total Amount of Water Pumped
in 4,000 hours..6.7 million litres

	Volume Flow Tests at 25 m (litres)			Leakage Tests at 7 m (ml/min)
Strokes/min	30	40	50	
New	0.69	0.69	0.69	0.1
After 1,000 hours	0.68	0.68	0.68	0.1
After 2,000 hours	0.66	0.68	0.66	0.2
After 3,000 hours	0.54	0.59	0.61	0.1
After 4,000 hours	0.70	0.70	0.70	0.1

The performance test was not repeated after the endurance test because the cylinder had been replaced. The results would therefore not have been comparable with the original performance data.

Chapter 3

CONCLUSIONS AND RECOMMENDATIONS

3.1 CA and GIT Conclusions

CA test data and GIT comments concluded that:

- The Honduran AID-type handpump is robust enough to be suitable for use in a developing country community water supply program if the local manufacturer has well established iron foundry skills and effective quality control procedures.
- There are a number of design changes that should be considered to improve the assembly and/or use of the pump (see Item 2.5).
- The flap-type foot valve is worse than redundant because it can break away and damage the plunger. The design and material for this valve should be greatly improved or it should be eliminated in favor of a brass foot valve.
- The misfit of the parts highlighted the need for using jigs and fixtures so that all similar parts would be interchangeable.

WASH is in agreement with all conclusions.

3.2 WASH Recommendations

After reviewing the CA report and GIT's comments, WASH feels that the following recommendations are justified:

Recommendation #1 (Design Changes): The CA test indicated that, while on the whole the design of the USAID-type handpump was satisfactory, there were several areas of possible design changes: a more resilient handle, enlarged flanges, a scalloped spout, and simpler handle, fulcrum, and crosshead mechanisms. Future redesign efforts should take these items into account.

Recommendation #2 (Foot Valve Modification): The modification or elimination of the leather flap-type foot valve should be given priority attention in any future redesign effort.

Recommendation #3 (Jigs and Fixtures): The use of jigs and fixtures should be made a part of any future manufacturing effort in order to ensure interchangeability of parts.

Appendix A

Details of Procedures Used to Test USAID-Type Handpumps at CA's Harpenden Rise Laboratory

TEST PROCEDURES

1. Obtaining Pumps

The test samples were sent to the Laboratory direct from the manufacturers. Two samples of each pump were obtained. One sample was installed in the test tower for the user trial, performance and endurance tests. The second was used for engineering assessments, and to provide a supply of spare parts for the endurance test.

2. Inspection

All the pumps were inspected on arrival at the laboratory.

2.1 The packaging was described and assessed for its suitability for export and for crude overland transportation.

2.2 The condition of the pumps was assessed, noting any defects on delivery.

2.3 Any literature supplied with the pumps was noted, and assessed for usefulness in installing or maintaining the pump.

3. Weights and Measures

3.1 The weights of the pumpstand, cylinder and connecting assembly were recorded.

3.2 The principal dimensions of the pump were recorded. These included, where applicable:

- the bore, the actual stroke and maximum usable length of the cylinder
- the nominal volume per stroke
- the maximum usable cylinder length
- the diameters of the rising main and pump rod
- the maximum outside diameter of the below-ground assembly

3.3 The cylinder bores were measured at five points along their length. A second series of measurements was taken at right angles to the first, to check for taper or ovality and to provide a datum for measurements of cylinder wear after endurance testing. With any flexible plunger seal, ovality within $\pm$ 0.5 mm is not significant, due to the compliance of the seal. However, the constant flexing induced by taper will accelerate fatigue failure and taper should therefore not exceed $\pm$ 0.1 mm

The surface roughness average (Ra) of the cylinder bores was measured in three places in a direction parallel to the cylinder axis.

3.4 Various ergonomic measurements were taken, as follows:

- maximum and minimum handle height
- platform height, where applicable
- angular movement of handle
- handle length
- velocity ratio of handle, measured as the ratio of the distance moved by the normal operating point on the handle to the resultant movement of the pump rod
- height of spout

Pumps were installed in accordance with manufacturer's instructions, where available. Pumps requiring a platform for which suitable information was not available were installed so that the handle height was approximately 900 mm at the mid-point of its travel, subject to a spout height not greater than 600 mm. These preferred heights were suggested by previous user tests of hand pumps tested for the ODA, see report no. Z9923.

4. Engineering Assessment

4.1 One sample of each pump was completely dismantled. The materials and methods of manufacture for each part were identified and assessed for fitness for purpose.

4.2 Based on the this evaluation the suitability for manufacture in a developing country was assessed in terms of the required manufacturing methods and skills.

4.3 The pump was assessed for ease of installation, maintenance and repair. This assessment was reviewed at the end of the test programme, see item 9.

4.4 Each pump was assessed for susceptibility to contamination and abuse, including:

- resistance to contamination by surface water
- whether sticks or stones could easily be pushed into the spout
- whether the fixings or other exposed parts of the pump could easily be pilfered or vandalised
- susceptibility to accidental impacts by domestic animals etc.
- susceptibility to heavy-handed or deliberately violent usage.

4.5 Any potential safety hazards were noted.

4.6 Design improvements were suggested, to eliminate or reduce:

- potentially costly or difficult manufacturing operations
- potentially unreliable aspects of design or manufacturing
- potential difficulties in installation, maintenance or repair
- potential safety hazards

NB These suggestions were reviewed in the light of results from the 4000 hour endurance test.

5. Pump Performance

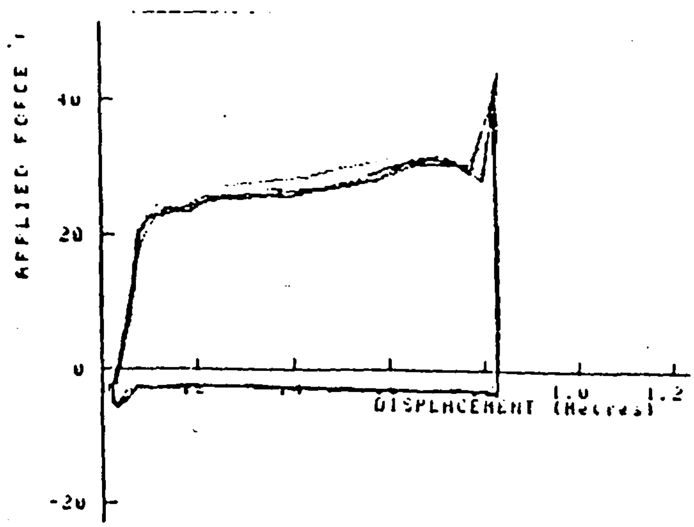
5.1 Apparatus Measurements of volume flow, work input and efficiency were combined in a single test method. Strain gauges were applied to the pump handle to measure the operating forces, while the movement of the handle was measured by a potentiometer. The outputs from the strain gauges and the potentiometer were fed, via an interface unit, to a microcomputer. The computer was programmed to record the data and calculate the work done on the pump as the product of the applied force and the displacement of the handle. The weight of water produced in each test was entered via the computer keyboard. The apparatus is illustrated in the Appendix.

Calibration The strain gauges were calibrated for each pump by noting the outputs corresponding to known weights, suspended from the handle at a fixed distance from the fulcrum, while it was locked in a horizontal position. The potentiometer was calibrated by noting the outputs for the upper and lower limits of handle travel, and the handle's length. This calibration procedure was built into the computer program and preceded each test.

Test Procedure Each pump was operated at three speeds, normally 30, 40 and 50 strokes or revolutions per minute. Where 50 strokes per minute would have been impractical or unrealistic, 20, 30 and 40 strokes/minute were used. For example with shallow-well pumps cavitation was evident at higher pumping rates. Some of the deep-well pumps when set at 25 or 45 metres required very high levels of operating effort, and full stroke operation at 50 strokes per minute was virtually impossible. All the pumps were tested at 7 metres head, the deep-well pumps also at simulated heads of 25 and 45 metres. The same person carried out all the tests, using a metronome to help the timing of his pumping rate.

For the reciprocating pumps, each test comprised 10 or 20 full strokes, depending on the rate of delivery of the pump. For the rotary pump, the tests were limited to 9 revolutions by the 10-turn potentiometer used to measure handle displacement.

Analysis The computer subsequently plotted the applied force against the displacement of the handle for each test. A typical result for a reciprocating pump is illustrated below. Successive strokes retrace the force/displacement loop. The area inside the loop represents the work done on the pump.



The computer also calculated the average volume flow, in litres per stroke or revolution, the average work input, in Joules per stroke or revolution, and the efficiency, thus:

$$\text{Efficiency} = \frac{Mh}{\Sigma Fd} \times 100 \text{ per cent}$$

where M = mass of water raised, kg
h = head, metres
F = applied force, kgf
d = handle displacement, metres

so that ΣFd = sum of the products of the applied forces and handle displacements
= work done on pump

Mh = useful work done by pump in raising water

6. User Trial

Sixty users were recruited. Adults, women and men, were divided in equal groups of short, medium and tall stature. Children, girls and boys of 11 or 12 years of age, were divided into short and tall groups:

6	Short Men	under 1.68 metres
6	Medium Men	between 1.68 and 1.79 metres
6	Tall Men	over 1.79 metres
6	Short Women	under 1.63 metres
6	Medium Women	between 1.63.and 1.69 metres
6	Tall Women	over 1.69 metres
6	Short Girls	between 1.35 and 1.49 metres
6	Tall Girls	between 1.50 and 1.65 metres
6	Short Boys	between 1.35 and 1.49 metres
6	Tall Boys	between 1.50 and 1.65 metres
60	total	

The shallow well pumps were operated at 7 metres head; the deep well pumps were set at a simulated head of 20 metres.

6.1 The users were asked to fill a 10-litre bucket with each pump and answer questions about the height and comfort of the handle, the effort required and the overall ease of use. Each user was given an opportunity to familiarise him/herself with each pump before being asked to fill the bucket. The users were instructed to work through the pumps in a controlled random order.

6.2 The users were methodically observed, to identify potential ergonomic difficulties in operating the pumps. Experience has shown that users may encounter difficulties of operation which are revealed by their bodily movements, although they are not themselves aware of them. The observations were reinforced by selective video recordings.

7. Endurance Tests

For the endurance tests, the pumps were mechanically driven in two batches, each of six pumps. The water discharged from each pump was directed into a hopper where the presence of water was monitored by float switches. When a pump failed, so that water was no longer discharged from the spout, the detector system switched off the motor for all the six pumps in that batch, a second detector then indicated the faulty pump. This ensured that all the pumps in each batch were subjected to the same endurance regime. The test continued around the clock until failure of a pump or the end of each 1000 hour interval. The drive mechanism did not impose shock loads on the pump handles.

The deep-well pumps were set at the start of the test at a simulated 45 metres depth, or at the manufacturer's specified maximum depth if less than 45 metres. If persistent failures were revealed, the depth was reduced. The shallow well pumps were operated at a depth of 7 metres.

All the force pumps were operated at 40 strokes or revolutions per minute, representing the highest speed likely to be sustained for any appreciable time in actual use. The shallow-well pumps were operated at 30 strokes/minute, the maximum speed for which cavitation under the piston was not apparent.

The pumps were lubricated at the beginning of the test but thereafter received no maintenance, except when any repair was carried out.

At the end of each stage, the volume flow and foot valve leakage were measured, to compare with the results of the performance test, and the cylinders were dismantled for inspection.

7.1 First 1000 hours - clean, hard water with an initial pH value between 7.0 and 7.8. This was the normal piped water supply to the laboratory.

7.2 Second 1000 hours - demineralised water to which hydrochloric acid was added to maintain a pH value of approximately 5.5, but not sufficient to raise the chloride concentration above 1 g/litre. In practice, the chloride concentration did not exceed 0.2 g/litre.

7.3 Third 1000 hours - hard water to which Kieselguhr, a hard, abrasive mineral, with an average particle size of 7.5 um, had been added in the proportion of 1 g per litre of water.

7.4 Final 1000 hours - hard water to which sharp quartz sand, with a particle size between 75 and 500 um, had been added in the proportion of 1 g per litre of water.

At the end of the endurance test, the pump performance was re-measured, as described in Section 5, for comparison with the earlier results.

8. Abuse Tests

The side impact tests were designed to assess the effect of domestic animals or people blundering into the pump. The impact energy was supplied by a simple pendulum. The mass of the pendulum consisted of a series of bags of lead shot, surrounded by sawdust and contained in a large canvas bag. This "careless cow" was suspended by a rope, pulled to one side to raise it an appropriate amount for the impact energy required, and released.

8.1 A series of side impacts on the mid-point of the pumpstand body, in 100 Joule increments to a maximum of 500 Joules.

8.2 A series of side impacts on the handle of the pump, in 50 Joule increments to a maximum of 200 Joules.

The handle shock loads were intended to assess the effect of accidental impacts of the handle against its stops during normal pumping. The test was not intended to represent deliberately violent abuse of the pump. The test was intended to be equivalent to 4000 hours of normal usage, assuming that an experienced pump user might allow the handle to hit the stops on average once in every 100 strokes.

8.3 The strain gauged handle was fitted, and the outputs from the strain gauges were displayed on an oscilloscope. The pump was operated manually, using normal levels of force but allowing the handle to "carry through" onto the stops on both the delivery and return strokes. The peak outputs of the strain gauges were noted. The handle was connected to a pneumatic drive system, which was then adjusted to produce similar peak strain gauge readings.

Force pumps were subjected to 96,000 impacts.
Suction pumps were subjected to 72,000 impacts.

9. Review

At the end of the endurance test, all the pumps had been dismantled and reinstalled several times and some had needed maintenance and repair. The appropriate topics of the Engineering Assessment were therefore reviewed in the light of this further information and experience:

9.1 Installation - an evaluation of the equipment, tools and skills required to install each pump successfully.

9.2 Maintenance and Repair - an evaluation of the equipment, tools and skills required to maintain and/or repair each pump successfully, with special reference to the requirements for Village Level Operation and Maintenance (VLOM).

Finally:

9.3 A verdict, summarizing in a few sentences the strengths and weaknesses of each pump, as revealed in the laboratory test programme.

Appendix B

Results of 1,000 and 4,000 Hours of Laboratory Testing of the USAID-Type Handpump by CA's Harpenden Rise Laboratory

Harpenden Laboratory
Harpenden Rise
Harpenden
Hertfordshire
AL5 3BJ
England

Tel 05827-64411
Telex: 826619 CALAB G

The Control Tower
Gosfield Airfield
Gosfield
Halstead
Essex CO9 1SA
England

Tel: 0787-472688

CA TESTING AND RESEARCH

Reply to: Ken J. Mills ...... at: Harpenden
Our Ref: KJM/EJW Date: 7 October 1982
Your Ref:
Your communication of:

The Managing Director,
Celco Industrial Company,
43A Jalan Jendral,
Gatot Subroto,
BANDUNG, Indonesia

Dear Sir,

LABORATORY TEST ON HANDPUMPS

We sent you on 2 February 1982 data checking sheets containing initial tests carried out on your handpump. The World Bank published this information in their report No. 1, March 1982 - Laboratory Testing, Field Trials and Technological Development.

The 4,000 hour endurance test period has now been completed and the attached summary shows how your pump performed. This information has been forwarded to the World Bank and in due course will be included in their final report on this present series of handpump tests.

If you have any comments about the endurance results, or any modifications you have made to your pump as a result of these laboratory tests, please let us know so that they can be incorporated in our final report to the World Bank.

The closing date for receiving of comments will be Friday, November 12th.

We look forward to hearing from you and if you would like any further information or help, please do not hesitate to let us know.

Yours faithfully,

Ken J. Mills
Testing Manager.

c.c. Saul Arlosoroff, World Bank

Pump Endurance Test Summary

CODE M: AID/BATTELLE

HOURS		VOLUME FLOW
248	Severe wear of handle, fulcrum link and pivot pin	
287	Connecting rod broken at thread on upper end	
416	Fulcrum link pin worn	
483	Pump rod broken at thread	
596	Connecting rod eye, handle and pivot pin badly worn	
989	Pump rod broken at thread - simulated head reduced from 45 to 30 m.	
1024	INSPECTION after 1st 1000 hours: a) Leather cup washers distorted b) Some corrosion of ferrous parts	GOOD
1076	Connecting rod broken at thread	
2037	INSPECTION after 2nd 1000 hours: a) Some wear in handle pins and bushes b) Piston valve somewhat worn on its circumference c) More corrosion of ferrous parts	GOOD
2474	Piston rod broken at thread - foot valve leather had rotted away allowing weight to foul piston causing rod to break. New foot valve assembly and piston rod fitted.	
3123	INSPECTION after 3rd 1000 hour stage: a) Bushes in handle fork worn through, pin approx. 50% worn b) Pump rod eye worn c) Some wear in crosshead guides and blocks d) Fulcrum link bushes worn at pump body pivot Holes in handle fork and pump rod eye bored out but not re-bushed. Stepped pivot pin made to suit and fitted.	GOOD

cont.

CODE M: AID/BATTELLE (cont.)

HOURS		VOLUME FLOW
4078	Piston rod broken at thread - foot valve leather had rotted away allowing weight to foul piston causing rod to break and damaging lower cup seal. New foot valve, piston rod and cup seal fitted.	
4130	FINAL INSPECTION	GOOD

1. Pumpstand

a) Noticeable wear on stepped pivot pin and connecting rod eye fitted at 3000 hour inspection
b) Other handle pivot pins and bushes also worn
c) Crosshead guides and blocks worn but still serviceable

2. Cylinder

Cylinder bore highly polished with no significant wear, though some scoring from sand particles - minor damage to cylinder bore from most recent piston rod breakage

3. Plunger

Both seals and valve in good condition

4. Foot Valve

Recent replacement still in good condition

5. Corrosion

Cylinder end caps heavily rusted - upper worse than lower.

JMR/EJW
7 October 1982

Harpenden Ris … oratory
Harpenden Rise
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Hertfordshire
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England

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Essex CO9 1SA
England
Tel 0787-472688
[redacted]
[illegible]

CA TESTING AND RESEARCH

Reply to: John Reynolds at: Gosfield
Our Ref: JMR/A9940 Date: 8 March 1982
Your Ref:
Your communication of:

The Managing Director
Celco Industrial Co.
43A Jalan Jendral
Gatot Subroto
BANDUNG
Indonesia

(F16)

cc: Mr E McJunkin - USAID
Mr S Arlosoroff - The World Bank
Mr K Mills - CATR

Dear Sir

AID/BATTELLE HAND PUMP

Further to Mr Ken Mills' letter dated 2 February 1982, covering the Data Checking Sheets from our interim test report, I enclose a summary of the AID/Battelle pump's progress through the first 1000 hour stage of endurance testing.

You will see that the pump has suffered several breakdowns.

The pump arrived with no instructions and no information as to the maximum depth at which it should be used. We could find no specific recommendation in literature from other sources, though it was suggested that the likely maximum depth for a three inch cylinder with two cup seals would be 150 feet. The head simulation valve was therefore set initially at 45 metres, just short of 150 feet. Because of the severe wear in the pumpstand and the repeated breakages of the connecting rod and pump rod, however, the simulated head has since been reduced to 30 metres, about 100 feet. I would be very grateful if you would confirm that this is an appropriate maximum depth for the pump in this configuration.

In re-assembling the pump after replacing the various worn parts, it has often been difficult to match components because of inconsistencies in the castings and misalignment of the drilled holes. It is likely that this misalignment contributes to the high rates of wear. We would urge that you give immediate consideration to improving your control of manufacturing quality.

We look forward to receiving the spare handle components requested in Mr Mills' letter.

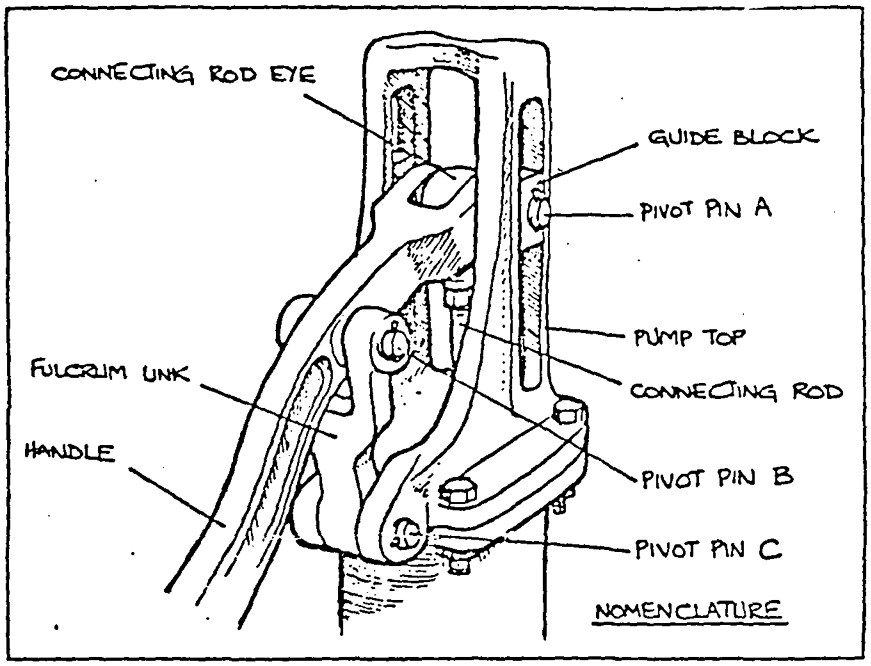
Yours truly,

John Reynolds

John Reynolds

AID/Battelle Pump - Summary of First 1000 hours Endurance Testing

NOMENCLATURE:



In the absence of specific instructions from the manufacturer, the pump was installed for endurance testing at a simulated head of 45 metres. Other literature suggested that this would be the likely maximum depth for the pump when connected to a 3 inch cylinder.

ELAPSED HOURS	
248	Severe wear of handle, fulcrum link and pivot pin B - pin broken and fulcrum link worn through. All these parts were replaced but assembly was difficult because the pivot pin holes in the various castings had not been drilled parallel.
287	Connecting rod broken at the thread where it attaches to the eye at its top end - the rod had been turned prior to threading, leaving a sharp shoulder, and this potential weakness was noted in the Engineering Assessment. The connecting rod was replaced.
483	The pump rod (not supplied with the pump) broke at the thread on one end. The rod used is mild steel, threaded 7/16th inch WHIT. similar to the connecting rod supplied with the pump.
596	Connecting rod eye badly worn, also the handle and pivot pin A, though guide blocks O.K. A new eye and pivot pin have been fitted, and the original handle (replaced at 248 hours) was re-bushed and re-fitted.
989	The pump rod broke once again, as at 483 hours. It has been replaced by mild steel rod of 1/2 inch diameter, threaded 1/2 inch. The head simulation valve was reset at 30 metres.
1024	End of 1st 1000 hour stage. No significant wear of PVC cylinder, though leather piston seals somewhat distorted. Noticeable rust on upper cylinder cap, piston rod and foot valve weight.

Appendix C

Pump Failure Alert Issued by CA's Harpenden Rise Laboratory Following Failure of Flap-Type Foot Valve

Harpenden Rise [illegible]oratory
Harpenden Rise
Harpenden
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AL5 3BJ
England

Tel: 05827-64411
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Gosfield Airfield
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England
Tel: 0787-472688
[redacted]

CA TESTING AND RESEARCH

Dr F E McJunkin
Chief, Water & Sanitation Division
Office of Health
Bureau for Science and Technology
Agency for International Development
WASHINGTON DC 20523
U.S.A.

Reply to: John Reynolds at: Gosfield
Our Ref: JMR Date: 5 May 1983
Your Ref:
Your communication of:

Dear Gene

I enclose two letters, and a copy of a third, sent to what we believed to be your address in Arlington, Virginia, but returned to sender. I hope this reaches you, and I'm sorry for the delay.

The enclosed letters will be self-explanatory, I hope, but I will take this opportunity to bring you up to date with the progress of the endurance test on the Funymaq pump from Honduras.

I enclose a Pump Failure Alert describing how the flap-type leather foot valve broke away from the base of the cylinder and caused considerable damage to the cylinder walls. The pump continued to work because the additional "Simmons" foot valve was undamaged, and the volume flow was reduced by only 20% or so, not enough to trigger the pump failure detector. This is the reason why the fault did not come to light until the pump was inspected after the third 1000 hour stage.

This reinforces our comment under "Suggested Design Improvements" in the Data Checking Sheets issued last December: see page 5, item 3. The flap-type foot valve is redundant and likely to be unreliable; it should be omitted.

The modest reduction in volume flow from the pump in spite of extensive damage to the cylinder bore is encouraging. It suggests that this cylinder configuration may tolerate a substantial degree of wear before it needs to be replaced.

I have sent the Pump Failure Alert to you rather than to the manufacturer, as I believe you suggested to Ken Mills. Please complete and return Part B of the PFA.

Many thanks, and kind regards,

John Reynolds

cc: Ken Mills

(6) enclosures

Diane - Please distribute as follows:
Original: OTD File
Copies: McJunkin
Wehman
Donaldson, WASH
Potts, GIT

PUMP FAILURE ALERT — PART A

PUMP: Funymaq
CODE: P

|_| Inspection — |_| Performance Test

PROJECT No: A9909

|_| Engineering Ass't — |_| User Trial

|_| Impact Test — |X| Endurance - state hours:

ELAPSED HOURS: 3127

---

1. MODE OF FAILURE

Tester(s): FPJ — Date: 20.4.83

The inspection at the end of the third 1000 hour stage of the endurance test revealed that the upper, flap-type foot valve had broken away from the cylinder end cap.

The valve had then fouled the plunger on the downstroke, bending the pump rod at the point of attachment to the plunger. The cylinder bore was deeply scored and the leather cup seals were damaged. The lower "Simmons" foot valve was unaffected and the pump continued to work. In spite of the damage to the cylinder and the cup seals, the volume flow was reduced by only 20% or so, compared to the original results when new.

Note that a similar foot valve failure occurred in the earlier test of the Sumber Banyu pump, after 2474 hours.

|X| Photographed? — Verified by: JMR — Date: 20.4.83

---

2. REMEDIAL ACTION TAKEN

Verified by: JMR — Date: 20.4.83

A new cylinder barrel and a new plunger, complete with cup leathers, were fitted.

The flap-type foot valve was not replaced.

|_| Photographed?

Actioned by: FPJ — Date: 20.4.83
Checked by: JMR — Date: 20.4.83

---

3. DESIGN IMPROVEMENT SUGGESTED?

|_| No — |X| Yes - describe:

This failure reinforces our comment under "Suggested Design Improvements" in the Data Checking Sheets issued in December, 1982: see page 5, item 3.

The proprietary "Simmons" foot valve makes the flap-type valve redundant. It is likely to be unreliable and may cause internal damage to the cylinder when it fails. It should therefore be omitted.

---

4. ROUTING

|X| Don Unwin)
)
|X| Ken Mills) CATR
)
|X| John Reynolds)

|_| Pump Manufacturer or Agent

|X| Client

|_| Project File

DATE SENT: 5.5.83

PUMP CODE: P

PROJECT No: A9909

Please complete and return to:

C A Testing and Research,
The Control Tower, Gosfield Airfield,
Gosfield, Halstead, Essex C09 ISA, England

5. MANUFACTURER'S COMMENTS and RECOMMENDATIONS

(a) Have you received reports of similar failures from the field?

|_| No

|_| Yes - please explain:

(b) Have you modified the pump in any way which relates to this mode of failure?

|_| No

|_| Yes - please describe:

(c) Has the pump been modified in any other way, or are other modifications under consideration?

|_| No

|_| Yes - please describe:

(d) If a potential design improvement has been suggested in Part A:

Do you agree that the suggested modification would improve the pump?

|_| Yes

|_| No - please explain:

(e) Further comments and recommendations:

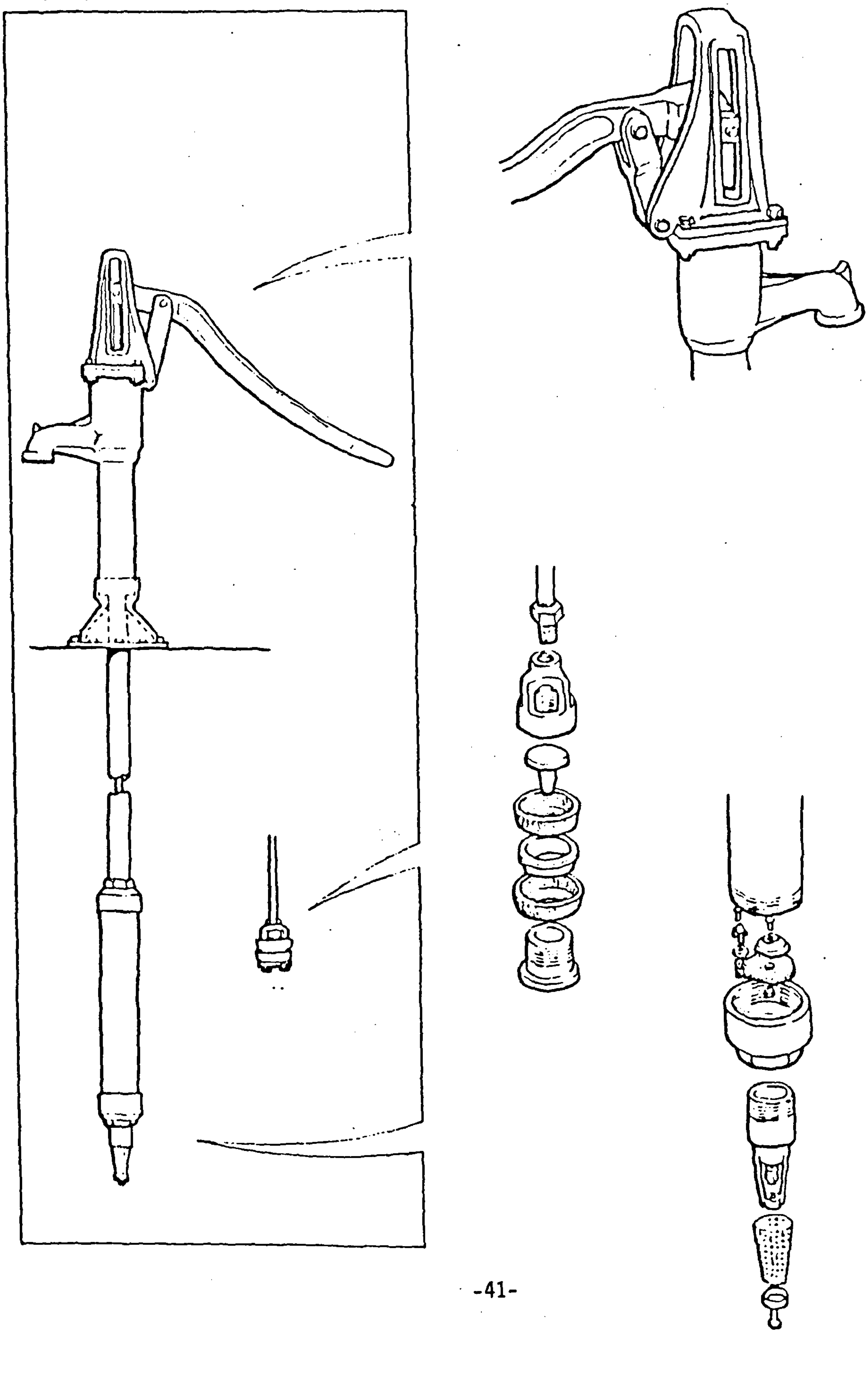
Name: Signature: Date:

Thank you.

Appendix D

Test Results from Laboratory Testing of USAID-Type Handpump By CA's Harpenden Rise Laboratory

Funyman



FUNYMAQ

1.1 Manufacturer

Funymaq, Honduras - supplied by the Georgia Institute of Technology

Address

Georgia Institute of Technology,
Engineering Experimental Station,
Atlanta,
Georgia 30332,
U.S.A.

1.2 Description

This pump is a derivative of a deep-well design from AID/Battelle for manufacture in developing countries. The pumps tested were made in Honduras. The pumpstand is mostly cast iron though the column is a length of steel tube threaded at each end. It features a crosshead mechanism to guide the top of the pump rod.

The cylinder design is conventional except that uPVC tube is used in place of the more usual seamless brass tube, with cast iron end caps. Two leather cup seals are used on the plunger. Two foot valves are fitted. The upper foot valve in the base of the cylinder is a simple flap of leather with a cast iron weight. The lower foot valve is a proprietary Simmons item.

Neither rising main nor pump rods were supplied with the pumps.

1.3 Price

Not known

2. INSPECTION

2.1 Packaging

The pumps were packed into an open-slatted wooden case and wired into position.

The pumpstand connecting rods were placed in the pump bodies and not secured. One fell through the bottom slats in transit and was bent. One handle was protruding from the side of the case.

The packing cases were strong, but their slatted construction made them unsatisfactory for export or for crude overland transportation. The cases should at least have solid bases.

2.2 Condition as Received

The pump tops would not fit the bodies - the holes were drilled in the wrong positions - and the holes in the pump cap did not provide sufficient room for the bolt heads. The handles were stiff to operate. One guide block was seized on its pin. The top section of one pump was not tight on the centre section.

One pump rod was bent in transit. Cast iron parts had not been flushed of casting sand. There was some evidence of porosity in some of the iron castings.

2.3 Installation and Maintenance Information

No literature was supplied with the pump.

3. WEIGHTS & MEASURES

3.1 Weights

Pump Stand:	51.0 kg (including handle)
Cylinder:	8.0 kg (including Simmons foot valve)

3.2 Dimensions

Nominal cylinder bore:	70 mm
Actual pump stroke:	190 mm
Nominal volume per stroke:	731 ml
Drop pipe size:	1.25 inch *
Pump rod diameter:	7/16 inch *
Outside dia. of below-ground assembly	105 mm
Maximum usable cylinder length:	320 mm

* Not supplied but designed for these sizes.

It is interesting to note that there are significant differences between this pump and the Sumber Banyu although both pumps were derived from the same design. In particular the castings of the Funymaq were a good deal heavier.

3.3. Cylinder Bore

No significant taper or ovality was found in either of the two samples.

The surface roughness average (R_a) was measured in three places in a direction parallel to the cylinder axis.

SAMPLE	CYLINDER BORE	ROUGHNESS AVERAGE (μm)			
		TEST 1	TEST 2	TEST 3	MEAN
1	Extruded uPVC	1.5	1.7	1.4	1.5
2	Extruded uPVC	1.5	1.5	2.0	1.7

Measured at 2.5 mm cut-off

3.4 Ergonomic Measurements

HANDLE HEIGHT		PLATFORM HEIGHT (mm)	ANGULAR MOVEMENT OF HANDLE (degrees)	HANDLE LENGTH (mm)	VELOCITY RATIO OF HANDLE	HEIGHT OF SPOUT (mm)
MAX(1) (mm)	MIN(1) (mm)					
1310	280	0	90	730	5.8	470

(1) Measured without compressing any bump stops

4. ENGINEERING ASSESSMENT

4.1 Materials of Construction

COMPONENT	MATERIAL(S)
Pumpstand top	Cast iron
Pumpstand column and spout	2 iron castings, 1 steel pipe
Handle	Cast iron
Fulcrum link	Cast iron
Handle fulcrum bushes	Hardened steel)Approximately
Handle fulcrum pins	Hardened steel)50 Rockwell C
Connecting rod	Steel
Eye	Cast iron
Cylinder	PVC body with cast iron end caps
Plunger assembly	Cast gunmetal
Cup seal	Leather
Foot valve in cylinder	Cast iron with leather flap
Simmons foot valve	Cast gunmetal with rubber seal

4.2 Manufacturing Techniques

The techniques required to manufacture the pump are listed below:

Above-Ground Assembly	Iron foundry Simple machining

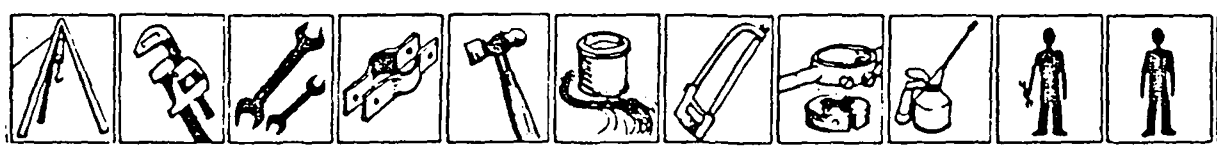
Basic skills in iron foundry and machining are required, but careful quality control is essential to ensure smooth operation of the handle assembly and interchangeability of parts for maintenance or repair. It is essential that the handle fulcrum pins and bushes are hardened. The pumpstand would be suitable for manufacture in developing countries with the appropriate skills, provided that the necessary quality control could be assured.

Below-ground Assembly	Iron and gunmetal foundry Simple machining Leatherwork

Basic skills in foundry work and machining are required. The cylinder would be suitable for manufacture in many developing countries.

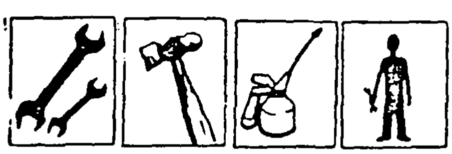
4.3 Ease of Installation, Maintenance and Repair

4.3.1 Ease of Installation



The Funymaq requires a substantial complement of tools and equipment and a good deal of skill or experience to install it. Lifting tackle would not be required if plastic rising main could be used.

4.3.2 Ease of Pumpstand Maintenance and Repair



The pumpstand is likely to require frequent lubrication of the handle and fulcrum link pivots. Eventually these components will need to be replaced but most tasks are easy, requiring only spanners and pliers, though a drift and hammer may be needed to remove the pivot pins.

If our samples were representative of normal production then replacement parts may not be interchangeable with original components, possibly making on-site repair impossible.

4.3.3 Ease of Below-ground Maintenance and Repair

The cylinder is likely to require frequent attention to the leather footvalve and possibly to consequent damage to the cylinder or breakages of the pump rod. Below-ground repairs require removal of the complete below-ground assembly.

4.4 Resistance to Contamination and Abuse

4.4.1 Resistance to Contamination

The spout should be modified to prevent possible faecal contamination. The pump is sealed against surface water but could be contaminated through the connecting rod hole. The connecting rod is a poor fit in the pump top.

4.4.2 Likely Resistance to Abuse

The split pins are easy to remove and there are no locking fixings. Otherwise the pumpstand is generally robust.

4.5 Potential Safety Hazards

There are a number of potential finger traps around the handle fulcrum mechanism and the guide blocks.

4.6 Suggested Design Improvements

A handle in a more resilient material than cast iron, such as steel or wood, where available, would be easier to repair.

The flanges on the pumpstand body and pumpstand cap should be enlarged to allow sufficient clearance for the heads of the fixings.

The check valve in the base of the cylinder should be omitted, or its quality should be improved and the proprietary foot valve omitted.

The spout should be vented or scalloped to prevent faecal contamination.

It is recommended that the design of the handle fulcrum be simplified and the crosshead mechanism eliminated.

5. PUMP PERFORMANCE

5.1 Volume Flow, Work Input and Efficiency

The description of the method can be found in the Test Procedure.

HEAD	7 m			25 m			45m		
Pumping Rate (strokes/min)	29	38	51	20	29	37	21	30	37
Vol/stroke (litres)	0.69	0.70	0.70	0.69	0.69	0.69	0.68	0.69	0.68
Work input/stroke (J)	125	134	134	2[illegible]1	277	304	404	459	468
Efficiency (%)	37	35	35	64	61	55	74	66	64

5.2 Leakage Tests

The measured leakage from the foot valves was not significant, i.e. less than 0.1 ml/min, at 7, 25 and 45 metre heads.

6. USER TRIAL

Details of the organisation of this trial can be found in the Test Procedure.

Most users seemed to operate the pump without difficulty. Many muscle groups could be called into play without exaggerated body movements.

7. ENDURANCE

A detailed description of the endurance test method can be found in the Test Procedure.

General Comments

The pump was tested at 40 strokes/minute at a simulated depth of 30 m.

The Funymaq pump proved to be much more durable than the Sumber Banyu pump tested in 1981/82, although both pumps were derived from the same design. In particular the handle pivots which had caused so much trouble in the Sumber Banyu pump endured throughout the test on the Funymaq. However, like the Sumber Banyu, the flap type leather foot valve broke away, in this case after 3127 hours. The pump continued to work because the Simmons foot valve supported the column of water, but the broken parts of the foot valve became entangled in the plunger, bent the pump rod and caused severe damage to the cylinder bore. It is strongly recommended that the flap type valve in the base of the cylinder should be omitted, or its quality should be much improved and the proprietary foot valve omitted.

Breakdown Incidence

Breakdowns are shown in bold type.

Hours: 0	1062	2112	3127	4169
Inspection and full performance test	Inspection and volume flow	Inspection and volume flow	Inspection and volume flow **Foot valve flap broken away, pump rod bent, severe damage to cylinder bore**	Inspection and full performance test

Details of the Endurance Test

Breakdowns are shown in **bold** type.

HOURS

1062 Inspection after 1st 1000 hour stage:

a) Slight wear in handle bearings and guide blocks
b) Spots of rust on cylinder end caps and plunger rod
c) Upper, leather foot valve appeared to be no longer functional and had been deformed into a constant, open position

2112 Inspection after 2nd 1000 hours:

a) Slight increase in wear in handle bearings and guide blocks
b) Larger spots of rust on cylinder end caps and considerable corrosion on plunger rod
c) Upper, leather foot valve redundant

8.2 Handle Shock Test

After 89,000 cycles, the top of the pumpstand had worked loose on its thread at the connection with the column, resulting in a leak. The thread was easily tightened and the pump remained in working order.

9. VERDICT

Different results were obtained for this Funymaq pump from Honduras than for the similar Sumber Banyu pump from Indonesia, although both pumps were derived from the same AID/Battelle design. In particular, the hardened handle fulcrum pins and bushes endured throughout the test, and the lift of the plunger valve and its location were better.

The leather foot valve is worse than redundant because it can break away and damage the plunger while the lower foot valve continues to support the column of water in the rising main. The damage is therefore worse than it would be if only one foot valve were fitted.

It is potentially suitable for community water supply, and for manufacture in developing countries with established iron foundry skills and effective quality control.

HOURS

3127 Inspection after 3rd 1000 hours:

a) **Severe damage to cylinder bore caused by parts of leather foot valve which had broken away and become entangled in the plunger. The plunger rod had bent and the cylinder bore was deeply scored as a result. The cylinder assembly was replaced by the second sample.**
b) Slight increase in wear in handle bearings and guide blocks
c) Further corrosion of cylinder end caps and plunger rod

Estimated Amount of water pumped to breakdown.............4.4 million litres

4169 Final Inspection

1	Cylinder	Replacement cylinder in good condition
2	Bearings	Considerable wear in handle bearings and guide blocks but all still servicable
3	Pumpstand	Hole in pumpstand top enlarged by connecting rod
4	Corrosion	Considerable corrosion of cylinder end caps and plunger rod, latter particularly around joint with plunger body

Estimated Total Amount of Water Pumped in 4000 hours......6.7 million litres

	Volume Flow Tests at 25 m (litres)			Leakage Tests at 7 m (ml/min)
Strokes/min	30	40	50	
New	0.69	0.69	0.69	<0.1
After 1000 hours	0.68	0.68	0.68	<0.1
After 2000 hours	0.66	0.68	0.66	0.2
After 3000 hours	0.54	0.59	0.61	<0.1
After 4000 hours	0.70	0.70	0.70	<0.1

The performance test was not repeated after the endurance test because the cylinder had been replaced. The results would therefore not have been comparable with the original performance data.

8. ABUSE TESTS

8.1 Side Impact Tests

Undamaged in both tests: body tended to turn on thread at joint with pumpstand column in handle test.

Appendix E

GIT Comments on CA's Report

T-72

Georgia Institute of Technology
ENGINEERING EXPERIMENT STATION
Atlanta, Georgia 30332

February 21, 1984

Camp Dresser & McKee Inc.
WASH FO PROJ

FEB 23 1984

Mr. David Donaldson
Water and Sanitation for Health Project
1611 North Kent Street, Room 1002
Arlington, VA 22209

Dear Mr. Donaldson:

Several days ago you asked for Georgia Tech's comments on Consumers' Association's report on the FUNYMAQ hand pump that was manufactured in Honduras. Our comments are as follows:

Page 14 (section 2.2)--The two pumps sent from Honduras were the first two manufactured by FUNYMAQ and were not representative of what was later produced when FUNYMAQ became more familiar with the pump manufacturing process. Despite Georgia Tech's strong protests, OTD 29 prohibited the expense of jigs and fixtures which are absolutely essential if parts are to be interchangeable. It is a mystery, however, as to why the pump caps would not fit onto the pump bodies since they fit prior to disassembly for shipment to England. As a result, Georgia Tech, you may remember, became so disenchanted with the prohibition of the making of jigs and fixtures that we, at our own expense, had them made by FUNYMAQ. The pump parts then became interchangeable with each other. It was a good lesson for us, and we now know that we will not enter into another manufacturing program under such a constraint.

Page 17 (section 4.3.3)--We agree with the comments on the leather foot valve. Even though the leather foot valve is very inexpensive to manufacture, it's reliability is low. Because Georgia Tech also was prohibited from using some other kind of foot valve in Honduras, the AID hand pump will most likely not be adopted for use by the Ministry of Health in Honduras.

Page 17 (section 4.6)--There is no data from Consumers' Association, including handle side impact tests and handle shock tests, to indicate that the handle should be of a more resilient material than cast iron. The problem of getting bolts through bolt holes was due to not using jigs and fixtures and cleared up when we began using this type of production tooling. We agree with the rest of the comments of section 4.6.

Page 18 (last paragraph on the page under general comments)--We agree, as stated earlier, with the comments on the leather foot valve.

page 19 (section on details of the endurance test)--Consumers' Association reports that there was a slight wear in handle bearing and guide blocks at 1,062 hours, a slight increase in wear in handle bearings and guide blocks at 2,112 hours, a slight increase in wear in handle bearings and guide blocks at 3,127 hours, and considerable wear in handle bearings and guide blocks at 4,169 hours. What is meant by "slight" or "considerable"? Laboratory tests at Georgia Tech show negligible wear of these components which will be supported by wear measurements. It would be helpful if the report showed the data reflecting the level of wear.

Page 21 (last paragraph on the page under verdict)--We agree with Consumers' Association's comments here except that we have the question of what is meant by "slight" or "considerable" wear of components as mentioned above.

In closing, we suggest that Consumers' Association clarify (1) why they have concluded that the cast iron handle should be of a more resilient material and (2) what is meant by "slight" or "considerable" wear of handle bearings and guide blocks.

Yours truly,

Phil Potts

Phillip W. Potts
Technology Applications Laboratory

PWP/lbh

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CA TESTING AND RESEARCH

Dr F E McJunkin
Agency for International Development
Room 702
1601 N Kent Street
ARLINGTON
Virginia 22209
U.S.A.

Reply to: John Reynolds at: Gosfield
Our Ref: JMR Date: 24.2.83
Your Ref:
Your communication of:

Dear Gene

Bearings for Pumps derived from AID/Battelle designs

At the Malawi seminar, you asked through Ken Mills about the possible use of acetal bearings in AID/Battelle-type pumps, based on the encouraging initial experiments on the Maldev unit. You must have seen the modified Maldev pump at Kandeu, and therefore appreciate that the acetal bearings were not fitted as a straight substitution for the ball races. The pump head had to be substantially modified for the new bearings.

We believe that many attempts to use plastics have failed because one material was substituted for another, without taking account of the relative properties of the materials and re-designing accordingly. Therefore, we do not feel the problems of Sumber Banyu pumps can be solved by simply substituting acetal bushes for the existing steel bushes. Moreover, our current tests on the Funymaq pump from Honduras have shown that the steel bearings will endure, if the pivot holes are parallel and the bushes and pins are hardened.

We therefore suggest the following procedure to deal with existing stocks of pumps which may be unsatisfactory:

1. Dismantle pumpstands.

2.1 Check parallelism in all planes of holes in fulcrum link;

2.2 Check parallelism in all planes of holes in handle;

2.3 Check parallelism in all planes of pivot holes in pumpstand, and check for squareness with top of pumpstand.

3.1 Check fit of fulcrum link over handle and between lugs in pumpstand top;

3.2 Check fit of handle in pumpstand top;

3.3 Check fit of guide blocks in pumpstand top.

/cont.

0656 03/12#
WASHAID 64552
TLX TO D DONALDSON VIA WUI 151 [illegible]
WASH PROJECT

FROM KEN MILLS DATE [illegible]

DATE 9/3/84

REF: 3016/JU

THANKS FOR YOUR TELEX 876

1)

TRUST YOU HAVE RECIEVED REVISED REPORTS [illegible] DATA POST 1.3.84.

2)

RE YOUR COMMENTS - ALTHOUGH NO TROUBLE WITH [illegible] HANDLE WE DID BREAK THE HANDLE ON NUMBER [illegible]. IT WAS LOWER QUALITY CASTING. THUS WITH THIS DANGER WE RECOMMEND MORE RESILIENT MATERIAL.

BY 'SLIGHT' WE MEAN APPRECIABLE WEAR BUT LITTLE REDUCTION IN COMPONENT LIFE. BY 'CONSIDERABLE' WE MEAN THE WORKING LIFE HAS BEEN REDUCED BY ABOUT HALF AND 'SEVERE' WE MEAN WORKING LIFE SO REDUCED THAT COMPONENT WILL NEED REPLACEMENT VERY SOON.

TRUST THIS IS CLEAR.

REGARDS

KEN MILLS#
WASHAID 64552

825519 CALAD G
VIA WUI

4. Put aside all pumps that are unsatisfactory, for rectification.

"Good" Pumps	"Bad" Pumps
5.1 Press out bushes	6.1 Press out bushes
5.2 Harden bushes and pins	6.2 Rebore holes oversize and correctly aligned
5.3 Reassemble	6.3 Make new oversize bushes
	6.4 Harden pins and bushes
	6.5 Reassemble
	Note that it may be sufficient to re-bore only one end of the fulcrum link, or only one hole in the handle, if the other end or hole is satisfactory.

7. Check cylinder end caps for porosity, and seal if necessary.

8. Remove leather flap foot valve, replace with proprietory foot valve as used in Honduras pump.

In the longer term, we feel the Battelle design could be adapted for acetal bearings, but that this is not the solution to your problem of an existing stock of pumps which may be unsatisfactory. If you would like us to undertake any work using the experience we are gaining from the use of this material in this application, please let Ken know.

Ken also asked me to mention that he has received from Saul Arlosoroff details of the new Hipps handpump. It would be very interesting to compare this system with the Abi-Vergnet hybrid pump and other lever arm pumps since the force required to operate it at 10 metres seems unusually high.

Sincerely,

John

John Reynolds

cc: Ken Mills, Don Unwin

WATER AND SANITATION FOR HEALTH PROJECT

COORDINATION AND INFORMATION CENTER

Operated by The CDM Associates
Sponsored by the U. S. Agency for International Development

1611 N. Kent Street, Room 1002
Arlington, Virginia 22209 USA

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Telex No. WUI 64552
Cable Address WASHAID

August 16, 1983

Mr. Henry Van, Ph.D.
Technology Applications Laboratory
Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30302

Dear Doctor Van:

In a series of reports and letters regarding the C.A. handpumps testing program that Mr. McJunkin recently delivered to this office, WASH has been made aware of a number of points. A review of this material resulted in several interesting observations:

A. Elimination of Foot Valve- The Pump Failure Alert sheet highlights the problem that can result from the destructive failure of the leather foot valve. (see Item I Mode of Failure). This failure highlights the need to replace the leather flapper valve with a better solution. In this regard we request that: 1) You review your field reports of Sri Lanka, Philippines and Honduras to determine the failure rates for this item in each country; 2) Complete and return Part B of the Pump Failure Alert Form; and, 3) Give WASH your recommendations for resolving this problem. (For example: eliminate flapper valve and install a brass check of X type). We look forward to your reply. You may also want to advise the manufacturer of this problem.

B. Bearings For AID Type Pumps- We call your attention to William Reynolds' letter of February 24, 1983, in which he addressed the use of acetal bearings as a substitute for the current steel on steel solutions. Any comments on this approach, will be welcome.

C. Testing of Moyno Handpumps- As of February 2, 1983, the Moyno handpumps had completed 6,000 hours of testing. The only failure (after 3175 hrs) was where the rubber buffer became entangled in the rotor.

In addition, I am pleased to enclose a copy of the report that C.A. provided to the handpump manufacturer in Indonesia. We suggest that you may want to consider developing a similar sheet to send to the manufacturers of the pumps being tested at GIT under T-69. Mr Reynolds' letter of March 8, 1982, also provides additional information regarding the testing of the Indonesia handpumps.

WASH

Mr. Henry Van
August 16, 1983
Page 2

The above information plus the material on the Honduras pumps that we sent previously, is all the material we have received from C. A.

We look forward to any comments and/or suggestions you would convey to make on the C.A. reports and/or procedures.

Very truly yours,

David Donaldson, P. E.
WASH Project Acting Director

DD/cr

Enclosure

cc Mr. V. W. Wehman, (S&T/H)